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METHOD, DEVICE, AND TEST SPECIMEN FOR TESTING A PART, AND USE OF THE METHOD AND DEVICE

The present invention relates to a method and a device for testing the detectability of at least one flaw in a component, or for evaluating an ultrasonic signal of the flaw; as well as a test specimen for implementing the method.

The metallic materials used for manufacturing heavy-duty components must satisfy stringent quality standards. Such components include, for example, rapidly rotating disks of turbine or compressor stages of a gas turbine that propels an airplane. Blades are attached to these disks. In such a material, flaws may occur that are caused by, in particular, the manufacturing process of the material. These flaws include casting bubbles, pores, inclusions, heat-treatment cracks, and welding cracks. Methods and devices are needed for detecting such flaws and quantifying the detectability of flaws.

The use of ultrasonics for non-destructive material testing is known from "Dubbel -- Taschenbuch für den Maschinenbau", 20th edition, Springer Publishing House, 2001, E33 and S87.

Test specimens and calibration specimens are used for the reliable and comparable testing of a component with the aid of ultrasonics. According to the related art, blocks having flat-top bores or cross bores are provided for this. These blocks are mostly made out of the same material as the part to be manufactured. Therefore, neither the shape and dimensions, nor the reflection characteristic and reradiation characteristic of real flaws are realistically described.

JP 2002-048773 A describes a device for calibrating an ultrasonic testing device. The method may be used for a testing device having one probe and for one having two probes. Several calibration holes are introduced into a welded component in a particular manner. The probe(s) are applied to the part and at specific angles to one another, and a characteristic curve for the distance between distance and amplitude is generated.

In U.S. 5,670,719, a system is described which ascertains the resolution of medical ultrasonic testing devices. The system predicts the local wounds or tumors in the tissue of a human that the testing device detects. A phantom container simulates human tissue. Wounds and tumors are simulated in several layers with the aid of scattering particles. It is determined, which particles are detected and which are not.

The object of the present invention is to provide a reliable method and a reliable device for testing the detectability and evaluating the shape, position, size, and orientation of flaws in a component.

This object is achieved by a method according to Claim 1, a device according to Claim 9, and a test specimen according to Claim 13. Advantageous embodiments are indicated in the dependent claims.

The method of the present invention comprises the following method steps:

- An electronic specification of at least one flaw is generated. The specification stipulates the position, shape, size, and orientation of the flaw or flaws. It includes a three-dimensional point pattern of the flaw or

flaws and defines, in this manner, the position of each point of the point pattern in a three-dimensional space.

- A test specimen is produced according to the specification. In this connection, for each point of the point pattern, a microcrack in the test specimen is produced at the position of this point, and therefore, a microcrack field representing the flaw is produced.

- Ultrasonic signals of the test specimen are recorded. Any ultrasonic method may be used for this. The ultrasonic signal is analyzed, for example, in the form of images generated from the signals. The evaluation of the ultrasonic signals includes at least the test of whether or not the deliberately produced flaw is detectable in the image. During the evaluation of flaws, the ultrasonic signals are assigned to the different flaws, in order to deduce the shape/type of the flaw from the signals in the case of real measurements on components.

The method shows a way of inexpensively selecting an arbitrary flaw and testing if this flaw is detected. In addition, the method shows a way to render visible how flaws manifest themselves in an ultrasonic signal of the component. Any number of flaws may be selected reliably and highly realistically with regard to size, shape, and position. After the signal is evaluated, the flaws that are detected and the flaws that are not detected may be quantitatively specified. This allows the method to reliably specify the real flaws, microstructures, and/or textures that can be detected in a component and the ones that cannot. Since the method allows the detectability of flaws to be specified, in particular with regard to size, shape, and position, the potential rigidity of the material may be reliably utilized in the design and

manufacture of the component, where neither flaws remain undetected, nor the component is overdimensioned and, therefore, the material apportioned too generously.

Realistic test cases may be rapidly produced, with the aid of which it is possible to select a complete spectrum of test cases. The produced flaws are generated in such a manner, that they come close to real flaws with regard to shape, reflective behavior, and reradiation or backscattering characteristic.

The method may also be used for testing or ascertaining the resolution of an ultrasonic testing system (Claim 8). Through use of the method according to the present invention, it is tested whether or not the ultrasonic testing system used for recording the image detects the purposefully generated flaws. It is possible to obtain information about the test sensitivity as a function of the dimensions, shape, and position of the flaws. This allows the method to test and guarantee a particular ultrasonic testing technology. For example, the applicability of a new ultrasonic testing technique may be tested. The method allows one to verify the resolution of the testing system (device, cable, converter) or testing method, which is used in the production of heavy-duty components. Such a verification is necessary, for example, for certifying rotating blades or disks for airplane engines and may be provided with the aid of the method.

The material, of which the test specimen is made, is not necessarily the same material that is intended or used for manufacturing the component. The method allows a material for the manufacture of the test specimen to be selected so that the microcracks in it may be produced simply or inexpensively. The test-specimen material does not have to withstand the same loads as the one intended for the component. The latter may

be high-strength steel, and from a standpoint of production engineering, it is difficult and expensive to deliberately produce flaws in this steel. Thus, the method points out a way of reducing costs. A material, which is less expensive or more suitable for the deliberate production of flaws than the one provided for the component, may be used for the test specimen.

The microcracks are preferably generated, using internal laser engraving (Claim 2). The generation of microcracks with the aid of internal laser engraving is known from DE 3425263 A1, DE 04407547 C2, DE 10015702 A1, and DE 19925801 A1. The microcracks may be generated particularly easily and rapidly with the aid of internal laser engraving. Through specific stipulation of parameters of the method for internal laser engraving, the microcracks may be generated precisely in predefined sizes in a microcrack field of predefined shape, size, and orientation.

Claim 3 provides for the microcracks to be generated in such a manner, that their largest dimension is smaller than the wavelength used for recording the ultrasonic image. In this manner, the shape of an individual microcrack is no longer discreetly reproduced. The flaw and its reflective behavior is only produced by the combination of microcracks, which is stipulated by the specification. This allows the shape and the dimensions of the deliberately generated flaw to be precisely specified, without the dimension of the microcracks influencing the result of the method. Which flaws are detected and which are not detected, is a function of the number and distribution of the points in the point pattern.

According to Claim 6, the material intended for the component and the material from which the test specimen is manufactured have approximately the same elastic parameters. This allows

the method to attain a particularly high degree of realism. If the method is used for ascertaining the resolution of the ultrasonic testing system, then the result of Claim 6 is that the resolution of an ultrasonic testing system in the test-specimen material comes particularly close to that in the component material.

In the following, the present invention is described with reference to an exemplary embodiment. In this exemplary embodiment, a disk, which rotates rapidly in a turbine stage of a turbojet engine, and to which turbine blades are attached, acts as a component. This disk is made out of a heavy-duty, nickel-based alloy. It would be expensive and time-consuming to make a test specimen out of this material and deliberately produce flaws in this test specimen, and in addition, it would not possible in all of the desired positions and orientations. On the other hand, the test specimen can be made in almost any shape, out of a material, whose acoustic characteristics are similar to those of the component material, and which is transparent to light, and test flaws may be produced in almost any size, shape, and orientation.

With the aid of an ultrasonic testing system, a plurality of ultrasonic signals of the test specimen is recorded. The resolution of an ultrasonic testing system is a function of the angle between the propagation direction of the ultrasound and the direction of the largest dimension of a flaw in the test specimen, and/or a function of the angle between the propagation direction and the surface of the test specimen. Thus, several ultrasonic signals of the test specimen are generated from different directions.

The method of the present invention may be used for ascertaining the resolution of an ultrasonic testing system,

based on the material provided for the component. For this purpose, several specifications are successively generated from microcracks. The specifications differ from each other such that each point pattern of a specification has a smaller maximum dimension than all of the preceding specifications. For each specification, a test specimen is produced according to the specification, and ultrasonic signals of this test specimen are generated by the ultrasonic testing system. It is checked whether or not the device detects a flaw in the test specimen. The method is interrupted when the testing device does not detect any flaw in the test specimen, which was manufactured according to the specification generated last. In this case, several signals are preferably generated from different angles, as well. The maximum dimension of the smallest detected flaw is used as a measure of the resolution of the testing system.

In addition, the method may also be used for producing a library of possible flaws in the component. A number of possible flaws are specified, each flaw being stipulated by a specification via a point pattern. For every possible flaw, with the aid of the method according to the present invention,

- on one hand, a test specimen in which the flaw is purposefully achieved is produced,

- and on the other hand, ultrasonic signals of this test specimen are generated.

An image of the test specimen and the ultrasonic signals of the corresponding test specimen are recorded for each flaw. Through evaluation of the signals, it is ascertained if the flaw is detectable in at least one of the ultrasonic signals. In addition, the number, shape, position, and position of the flaws detected in the ultrasonic signal are preferably

compared to the specification and/or to the flaws deliberately produced in the test specimen.

The library makes it easier to evaluate ultrasonic signals of a manufactured component and to make conclusions from the ultrasonic signals of the component, regarding the presence and the type, position, and dimension of flaws in the component.